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Characterizing supply chain visibility – a literature review

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Abstract

Purpose – The purpose of this paper is to present a literature review that aims to provide insight into the characteristics and effectiveness of supply chain visibility (SCV), as well as to identify metrics that capture these aspects in business processes.
Design/methodology/approach – A systematic review of the supply chain literature is conducted to identify the characteristics and the effectiveness of SCV. The synthesis of SCV effectiveness and its metrics are based on the process-oriented approach which relates the effectiveness of SCV to improved business performance.
Findings – This study reveals that the characteristics of SCV can be captured in terms of the accessibility, quality, and usefulness of information. The benefits of SCV are found to extend beyond improvements to operational efficiency of business processes or to the strategic competencies of an organization.
Practical implications – This study underlines that clear agreements between all players involved in the SC can help to solve problems caused by information completeness (type and amount of information), and unlock the full potential of SCV projects.
Originality/value – By using a process-oriented approach, this review provides a comprehensive explanation of the functions of SCV, as well as its first-order effects, in terms of automational, informational, and transformational characteristics.

Keywords Australia, Supply chain management, Literature review, Europe, Supply chain visibility, North America, Information visibility, Process-oriented perspective

Paper type Literature review

1. Introduction

Supply chain visibility (SCV) refers to the extent to which actors within the supply chain (SC) have access to the timely and accurate information that they consider to be key or useful to their operations (Barratt and Barratt, 2011; Barratt and Oke, 2007). More specifically, it refers to the visibility of demand and inventory information across the SC. Improved visibility about customer demands and inventory levels increases the accuracy of demand forecast, accelerates the adjustment of production plans to match changed demands, improves delivery performance, and reduces the amount of inventory in all levels of the SC (Barratt and Barratt, 2011; Bartlett *et al.*, 2007; Bottani *et al.*, 2010; Goel, 2010; Heah and Omar, 2005; Kim *et al.*, 2011; Rai *et al.*, 2012). SCV from first-tier suppliers to end customers, so-called end-to-end SCV, enables SC partners to achieve a higher level of market responsiveness and mitigate the risk of disruptions to the flows of materials and products (Butner, 2007; KPMG International Cooperative, 2016; Wei and Wang, 2010). End-to-end visibility is highly recommended as the best way to reduce the risk of SC failure and to improve SC analytics (KPMG International Cooperative, 2016). Yet, in most SCs, SCV is far from being fully achieved (KPMG International Cooperative, 2016).

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Among various obstacles, a lack of common SCV metrics has been identified as a critical concern and challenge for SC managers, which detains SCV from further development and implementation in organizations (Butner, 2010; McIntire, 2014). The lack of a clear definition of the characteristics of SCV has made it difficult to evaluate the effectiveness of a SCV project and, as a consequence, hinders the progress of promoting such projects (McIntire, 2014).

This study reviews the literature in order to provide a systematic analysis and synthesis (Denyer and Tranfield, 2009) of the main characteristics of SCV and to identify the metrics by which SCV effectiveness is evaluated in business performance. We agree with McIntire (2014) that SCV is a process that can be measured in terms of its effectiveness. Accordingly, the characteristics of SCV provide a basis for understanding the functions of the process and suggest metrics for evaluating its effectiveness. As the characteristics and effectiveness of SCV are ambiguously defined this study uses an interpretive approach, by which the literature is synthesized and interpreted in order to build theoretical constructs (Rousseau *et al.*, 2008). We investigate articles to locate the characteristics of SCV and then categorize similar characteristics into a number of key concepts, based on repetitive readings and constant comparisons of the details in each study.

Our exploratory review of the relevant literature reveals three broad characteristics of SCV that relate to the accessibility, quality, and usefulness of information (e.g. Barratt and Oke, 2007; Bartlett *et al.*, 2007; Caridi *et al.*, 2010; McIntire, 2014; Williams *et al.*, 2013). On the one hand, we observe that several studies focus on the characteristics and effectiveness of SCV from an "information exchange" dimension: the improvement in business performance (i.e. stock reduction, delivery adherence) is considered an immediate effect of the relative improvement in the "accessibility" and "quality" of information sharing and information technology adoption (Brandon-Jones *et al.*, 2015; Caridi *et al.*, 2010; Kim *et al.*, 2011; Williams *et al.*, 2013; Zhang *et al.*, 2011). On the other hand, various studies argue that the effectiveness of SCV has a "usefulness" dimension and emphasize the utility of information in business operations (Barratt and Oke, 2007; Caridi *et al.*, 2014; Kaipia and Hartiala, 2006; Lee and Rim, 2016; McIntire, 2014; Pfahl and Moxham, 2014; Wei and Wang, 2010). In line with both streams of articles, we take into account the accessibility and quality of information sharing, as well as the utilization in business processes, to define explicable and practical metrics of the characteristics and the effectiveness of SCV.

We observe that, to a great extent, the literature relates the characteristics of SCV to the accessibility of information, the quality of information, and the usefulness of information for business process improvement. We therefore identify the process-oriented approach to business value assessment as a useful theoretical framework to synthesize the metrics for evaluating the effectiveness of SCV. The process-oriented approach focuses on the interrelationship between information, technology, and business processes; moreover, it evaluates the values of information and technology in terms of critical improvements in operational or managerial processes (Mooney *et al.*, 1996; Visich *et al.*, 2009). Such critical improvements in business processes are classified as automational, informational, and transformational effects (Mooney *et al.*, 1996; Visich *et al.*, 2009). The automational effect refers to the use of technology to substitute labor in the processes. The informational effect emphasizes the management of information and mainly refers to collecting, storing, processing, and forwarding information for the purpose of capturing process information. The transformational effect relates to the application of information to facilitate and support business process innovation and transformation. Based on the process-oriented framework, we relate the characteristics and effectiveness of SCV to improved business performance: we link the accessibility and quality of visible SC information to the use of information in business operations. We thus apply the concepts of the process-oriented approach to explain the functions of SCV. This allows us to define the automational effect of SCV as the ability to

capture and transfer required information by means of information and communication technologies (ICT). The informational effect refers to the quality of information that is collected and distributed among SC members. The transformational effect of SCV is analogous to the utilization of information and accordingly reflects the alignment of information with business processes in order to improve operational efficiency or increase strategic competencies. It indicates that the extent to which information from SC partners is utilized in business processes and induces process improvement.

The paper is further structured as follows. In Section 2, we explain the research synthesis method used. Section 3 defines the main characteristics of SCV. Section 4 explains the analytical methods used to evaluate SCV. In Section 5, we discuss the findings and suggest topics for future research, while the last section presents the conclusion.

2. Systematic review method

To undertake this literature review, we followed the guidelines in Denyer and Tranfield (2009), which provide a protocol to help researchers formulate a research question and define the boundaries of a literature review, locate studies, evaluate and select appropriate studies, and analyze and synthesize the selected evidence. We explain each of these steps below and apply them to our study on SCV.

2.1 Research questions and boundaries of the literature review

The "fit for purpose" protocol (Macpherson and Jones, 2010) is useful to search a heterogeneous body of research. This protocol suggests selecting studies that contain sufficient information to explain the characteristics of SCV as defined at the outset of the review. Since the first objective of the research is to analyze the characteristics of SCV and how SCV is evaluated, we formulate the following research questions:

RQ1. How does the extant SCV literature distinguish the characteristics of SCV?

RQ2. How does the extant SCV literature assess the effectiveness of SCV?

Based on these insights, the next research objective is to identify metrics that are capable of evaluating the effectiveness of SCV and, at the same time, link the effectiveness of SCV to business performance. Following the process-oriented approach, which provides a useful framework for this analysis, we introduce the concepts of automational, informational, and transformational effects to synthesize these metrics. Accordingly, we formulate the next research questions as:

RQ3. How can the characteristics of SCV be related to its automational, informational, and transformational effects?

RQ4. What are the metrics for assessing the effectiveness of SCV?

2.2 Location of the studies

We focus on peer-reviewed articles from SC management disciplines. In order to identify relevant studies, we applied two searching methods: the protocol-driven method, which defines the search strategy at the outset of the study, and the snowballing method, whereby the location of studies emerges as the study unfolds (Greenhalgh and Peacock, 2005). We electronically searched three databases provided by EBSCOhost (Econlit, Business Source Premier and Academic Search Complete). These databases cover a wide range of business and economics publications. We used "SC" and "visibility" and "measurement or assessment or measures or effects" as the search strings and keywords because we distinguish SCV from simple information sharing. We found 77 articles which contain these keywords in the title or in the abstract. These articles were published between 1993 and 2016.

To locate additional relevant articles which are missing from the protocol-driven methodology, we applied the snowball sampling method (cross-referencing). In this way, we found another eight studies, so the total search resulted in a set of 85 studies.

2.3 Study selection and evaluation

Table I provides an overview of the inclusion and exclusion criteria used to investigate the relevance of the 85 articles under study. The selected articles should contain one or several of the properties listed in the left column. The right column provides the exclusion criteria for our study.

We used a two-stage appraisal for study selection and evaluation. In the first stage, we removed the irrelevant studies by reading the abstracts to select only the papers that focus on the inclusion criteria. The screening questions in this stage were "Is this study relevant to the characteristics of SCV?" and "Is this study relevant to the assessment of SCV?" In the second stage, we assessed the relevance of each study using criteria based on the general quality checklist produced by the Critical Appraisal Skills Program (CASP). The CASP checklist provides a useful filter to screen a wide range of potentially interesting papers and to narrow down the search to a smaller number of relevant studies. The checklist items were modified to fit the scope of our research synthesis. The purpose of the CASP tool is not to judge the quality, but to evaluate and report the limitations of the studies in terms of the clear identification of SCV characteristics and the calculation methods of the effectiveness. Finally, we kept 48 studies for analysis in this review.

2.4 Analysis and synthesis

In line with Denyer and Tranfield's (2009) guidelines, we broke down individual studies into constituent parts and analyzed how each part relates to the others. We began the analysis by reviewing the definitions of SCV in the literature. Table II provides a list of definitions of SCV that appear in 27 of the 48 selected articles. These definitions refer to various characteristics of SCV, which we labeled "accessibility," "quality," and "utilization of information being exchanged." However, the original articles do not clearly delineate the boundaries of each characteristic. For example, it is not certain whether "access" refers to the capability of a firm to capture information at the right moment or to the ability to share information across organizations. Likewise, information quality aspects such as "timeliness" and "completeness" of information are vaguely defined and subject to researcher interpretation of the appropriate time scale and the amount and type of relevant information. Most important is the lack of common criteria used to interpret the "usefulness" of information. It is obvious that the definitions of SCV in the existing literature are contemplated from different perspectives and therefore do not capture the same functions and requirements (Zhang *et al.*, 2011).

Inclusion criteria	Exclusion criteria
Definition of SCV	Non-English language
Characteristics of SCV	Non-academic papers
Relationship (interaction) between the characteristics	Marginal reference to the topics set in the inclusion criteria
Types of visibility	
Utilization of information in business processes (the act of using information, and the outcome of that use)	
Assessment of SCV	
Effect of the characteristics to the level of visibility	

Table I. Inclusion and exclusion criteria used to select the articles for the literature review

Authors	SCV definition
Balasubramanian *et al.* (2002)	Sharing information about all the links involved in managing the flow of products, services, and information
Barratt and Oke (2007) and Barratt and Barratt (2011)	The extent to which actors within a SC have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit. Visibility has a range of levels determined by the amount of useful information that is shared across the SC
Bartlett *et al.* (2007)	The management of upstream and downstream relationships with suppliers and customers in order to create enhanced value in the final market place at less cost to the SC as a whole
Brandon-Jones *et al.* (2014)	Information flows concerning inventory and demand levels within the SC at a given time
Caridi *et al.* (2010, 2014)	The ability of the focal company, i.e. the SC leader, to access/share information related to the SC strategy and the operations of SC partners
Chan (2003)	Quality of information transferred between suppliers, manufacturers, distributors, and customers
Francis (2008)	Identity, location, and status of entities transiting the SC, captured in timely messages about events, along with the planned and actual dates/times for these events
Goswami *et al.* (2013)	Having access to relevant information that can be used for various SC-related decision making
Griffiths *et al.* (2009)	The ability to see, understand, and react intelligently to market, environmental and process requirements within limited periods
Holcomb *et al.* (2011)	The extent of information visible to supply chain partners
Jeyaraj and Sethi (2012)	The ability to access or view pertinent data or information as it relates to logistics and supply chain, regardless of the point in the supply chain where data exists
Jonsson and Mattsson (2013)	A potential outcome of information sharing: making the supply chain more effective
Kaipia and Hartiala (2006)	The sharing of all relevant and meaningful information between SC partners, also over echelons in the chain
Kim *et al.* (2011)	The extent to which information/knowledge related to SC cooperation from partner firms is visible to the focal firm through the inter-organizational information system
Klueber and O'Keefe (2013)	The ability to provide and access information elements at a level chosen by relevant SC stakeholders
Lee and Rim (2016)	Process visibility, with a focus on operational capabilities
McIntire (2014)	A process of four meta-steps: capture information, integrate information, create intelligence and interrupt decisions. Either the information being collected or the decisions being interrupted should be supply chain oriented, and should span outside of a single organization's boundaries
Narasimhan *et al.* (2006)	The availability of and the access to information across the SC
Nooraie and Parast (2015)	The capability of sharing on-time and accurate data on customer demand, amount and location of inventory, cost of transportation, and other logistics dimensions throughout an entire SC
Rai *et al.* (2012)	A unified detailed view of inventory positions and in-transit shipments in the interfirm logistics process and the cascade alerts on critical events
Vigtil (2007)	The willingness of customers to share demand information and the ability of suppliers to apply the shared information for planning purpose
Wang and Wei (2007)	The degree to which SC partners have on-hand information related to demand and supply for planning and control
Wei and Wang (2010)	The degree to which SC partners have access to information related to SC operation and management and are considered to benefit each other
Williams *et al.* (2013)	The access to high quality information that describes various factors of demand and supply
Zhang *et al.* (2011)	The capability of a SC actor or player to have access to or to provide the required timely information/knowledge about the inventory involved in the SC from/to relevant SC partners for better decision support

Table II.
Definitions of supply chain visibility

To gain further insight into the distinct characteristics of SCV and to better delineate them, we thoroughly analyzed text fragments in the articles dealing with these characteristics. This process led us to identify seven key concepts as subcategories of the characteristics. "Accessibility" comprises the ability to capture information and the ability to transfer or integrate information. "Quality" includes the timeliness, accuracy, and completeness of information. And "usefulness" can be refined as both the utilization of information to improve operational processes and the utilization of information to improve strategic competencies. This step was time consuming because these seven key concepts were gradually developed during the review process and required repetitive readings (Campbell *et al.*, 2003; Noblit and Hare, 1988). Table III provides samples of the relevant text of the articles included in our literature review, and tabulates them under each characteristic. By extracting the seven characteristics of SCV from the existing studies, as shown in Table III, this step in the analysis provides answers to our first set of research questions.

In the next step, we analyzed and synthesized the key concepts of SCV from a process-based perspective, i.e. in terms of their automational, informational, and transformational effects. In this way, we were able to identify the functions of SCV in business processes and propose the metrics related to their performance. The automational characteristic comprises two sub-characteristics: automated information capturing and automated information transfer/integration. The informational characteristic concerns the quality of the exchanged information and comprises three sub-characteristics: information accuracy, information timeliness, and information completeness. The transformational characteristic indicates the meaningfulness of the information. It comprises the use of information to improve operational efficiency and strategic competencies. We also searched for appropriate metrics that would indicate the effectiveness of the main characteristics and sub-characteristics (key concepts). We extracted the metrics from the articles, identified the processes on which these metrics work, classified the metrics in accordance with the main characteristics and business processes, and then synthesized them in order to simplify readings. The outcome of these analyses and synthesis is explained in the next section, where we discuss each of the main characteristics and their metrics in detail. The overview of this discussion is summarized in Table IV and provides answers to our second set of research questions.

3. Main characteristics of SCV: a basis for evaluating SCV effectiveness

3.1 Automational characteristics

This first set of SCV characteristics is related to information technology as an enabler to acquire and distribute information among SC members. Automational characteristics refer to the ability to capture and transfer the necessary information in a timely manner by using ICT in diverse forms and methods. Existing the SCV literature addresses the automational characteristics of SCV as a function of using technologies to capture the granular details of information related to the flow of products along the SC (Delen *et al.*, 2007; Francis, 2008; Griffiths *et al.*, 2009; Musa *et al.*, 2014; Papert *et al.*, 2016; Rai *et al.*, 2012) and to coordinate the flow of information between partners in the SC (Barratt and Barratt, 2011; Bartlett *et al.*, 2007; Cherrett *et al.*, 2015; Kim *et al.*, 2011). Automational characteristics relate to inter-organizational information system (IOIS) visibility (Goswami *et al.*, 2013; Kim *et al.*, 2011), which emphasizes the role of the information system as an integral part of SCV with the intention to improve the visibility across organizational boundaries. The embedded IOIS means that the IT infrastructure between the buyers and suppliers is compatible and that information flows automatically between corporate information systems. The IT characteristics of SCV are also found in Barratt and Barratt (2011) in which the medium that is used for sharing information between the focal company and its suppliers is the determinant of a distinctive SCV. Similarly in Bartlett *et al.* (2007), IT is incorporated in the enhanced visibility project between the focal company and its suppliers. Production and

Table III.
Examples of text parts on SCV characteristics in the articles analyzed

Authors	Details of SCV	Key concepts of SCV characteristics						
		Ability to capture information	Ability to transfer/ integrate information	Information timeliness	Information accuracy	Information completeness	Utilization of information to improve operational efficiency	Utilization of information to improve strategic competencies
Barratt and Oke (2007)	"Visibility has a range of levels determined by the amount of useful information that is shared across the supply chain" (p. 1218). "VRINN [rare and not imitable] capabilities give a distinctive visibility that is capable of providing a sustainable competitive advantage" (p. 1222)					X	X	X
Barratt and Barratt (2011)	"The issue is not about [the extent of] information sharing but rather about the quality, timeliness and usefulness of the information in creating visibility that leads to the meaningful operational benefits" (p. 515)			X	X	X	X	
Bartlett *et al.* (2007)	"Sharing of information through E-space (electronic transfer of information) and data repository system" (p. 303). "Frequent exchange of information […] and that information should lead to action (e.g. joint initiative)" (p. 312)	X	X	X			X	
Caridi *et al.* (2010)	"All member of a given [supply] chain should have access to updated information and performance figures regarding the main processes of their partners […] to improve their operational efficiency" (p. 594)	X		X	X	X	X	
Griffiths *et al.* (2009)	"Accurate data, rapid data capture, immediacy of information and item-attendant convenience" (p. 176). "Delivery of accurate and timely information" (p. 173).	X		X	X			

(*continued*)

Table III.

Authors	Details of SCV	Key concepts of SCV characteristics: Ability to capture information	Ability to transfer/ integrate information	Information timeliness	Information accuracy	Information completeness	Utilization of information to improve operational efficiency	Utilization of information to improve strategic competencies
Kaipia and Hartiala (2006)	"Sharing demand information between retailers, distributors, manufacturers (OEM and CEM plants) and suppliers" (p. 13). "Demand information is meaningful only if operational efficiency can be improved through their use" (p. 15)	X				X	X	
Kim *et al.* (2011)	"The extent of visible information through the dedicated inter-organizational information system" (p. 668). "Visibility reflects the asymmetry in terms of the scope and depth of the partner information" and "Asymmetric visibility may increase the possibility of opportunistic behavior by trading partners" (p. 668)		X			X		
Klueber and O'Keefe (2013)	"Ability to provide and access information […] considering the influences of strategic orientation, stakeholder capabilities, supply chain compliances, operational flexibility, and environment" (p. 300). "SCV assessments are considered by the level of "networkability – the capability of an organization to establish, maintain and develop relationships with other organizations in order to pursue new common business opportunities or improve the results of an existing business through co-operation" (p. 301)	X	X				X	X
Lee and Rim (2016)	"SCV is the visible level which manifests the status and behaviors of various factors in the						X	X

(*continued*)

Table III.

Authors	Details of SCV	Key concepts of SCV characteristics: Ability to capture information	Ability to transfer/ integrate information	Information timeliness	Information accuracy	Information completeness	Utilization of information to improve operational efficiency	Utilization of information to improve strategic competencies
	supply chain, the ability for sensing and sharing variability in the supply chain process, the process maturity achieved by improvement initiatives for the key factors of the supply chain, and a predictable level for the viable degree of supply chain plan and outcome of process's activity" (p. 5)							
McIntire (2014)	"Increased awareness of the states of the supply chain activities and related events" (p. 11). "A process of four meta-steps: capture data, integrate data, create intelligence, and interrupt decisions. Either the data being collected or the decisions being interrupted should be supply chain oriented, and should span outside of a single organization's boundaries" (p. 24)	X				X	X	X
Nooraie and Parast (2015)	"SCV incurred if a product is supplied by the relevant suppliers in a given period" (p. 193)			X			X	
Pfahl and Moxham (2014)	"Effective use of information – utilize their information to make better decisions" "the availability of information itself does not constitute an advantage. What is more important is how this information is utilized in decision-making processes" (p. 556)						X	
Rai *et al.* (2012)	"Capture granular, detailed information," "Cascade alerts on exceptions that have occurred or are expected to occur" (p. 239)	X				X	X	

(*continued*)

Authors	Details of SCV	Key concepts of SCV characteristics						
		Ability to capture information	Ability to transfer/ integrate information	Information timeliness	Information accuracy	Information completeness	Utilization of information to improve operational efficiency	Utilization of information to improve strategic competencies
Wang and Wei (2007)	"Timely, accurate and relevant information" (p. 651)			X	X	X		
Wei and Wang (2010)	"The extent to which a firm can acquire real-time external information and quickly recognize changes in the environment" (p. 239), "The extent to which a firm can learn and gain new information and knowledge from its supply chain partners" (p. 240)	X		X	X	X		X
Williams *et al.* (2013)	"Acquisition of multiple types of high quality supply chain information," "In order for information to be of high quality, it must be accurate, timely, complete, and in usable forms" (p. 545)			X	X	X		
Zhang *et al.* (2011)	"The capability of a supply chain actor (or player) to have an access to or to provide the required timely information/knowledge," "which can be accessed via IT system" "Timeliness is an important factor for inventory visibility," "The capability to provide or access information must be measured using a timeliness metric" (p. 579)	X	X	X		X		

Table III.

Table IV.
Main characteristics of supply chain visibility

Main characteristics	Definition of main characteristics	Sub-characteristics	Metrics[a]	Definition of metrics
Automational characteristics	Ability to capture the essential information and to disseminate or integrate information across the SC	Automated information capturing	Level of AIDC technologies used to capture the information	The extent to which firms use technologies to capture information on events, status of stocks, flows of shipments, and exceptions e.g. shipment delay (Cherrett *et al.*, 2015; Delen *et al.*, 2007; Francis, 2008; Goel, 2010; Papert *et al.*, 2016; Pfahl and Moxham, 2014; Musa *et al.*, 2014; Rai *et al.*, 2012; Yu and Goh, 2014; Zhou and Benton, 2007)
				The extent to which firms use technologies to capture demand information e.g. sales data (POS or forecast), sell-through data or replenishment data, and stock withdrawals (Barratt and Oke, 2007; Bottani *et al.*, 2010; Kaipia and Hartiala, 2006; Vigtil, 2007; Williams *et al.*, 2013)
		Automated information transfer/ integration	Level of IOIS systems used to transfer/integrate information	The percentage of information provided in electrical format (Zhou and Benton, 2007)
				The extent to which the buyers and suppliers information is visible through inter-organizational information systems (Barratt and Oke, 2007; Bartlett *et al.*, 2007; Brusset, 2016; Chew *et al.*, 2013; Goswami *et al.*, 2013; Jeyaraj and Sethi, 2012; Kim *et al.*, 2011; McIntire, 2014; Rai *et al.*, 2012; Vigtil, 2007)
				The ability to disseminate the relevant information to community members using mobile, 3G and smartphone applications (Cherrett *et al.*, 2015)
Informational characteristics	Extent of qualified information shared among upstream and downstream members of a SC	Information timeliness	Frequency of information sharing (information updating)	How often major customers and suppliers provide information with the firms, e.g. daily, weekly, monthly and quarterly (Zhou and Benton, 2007)
				How often information is updated, e.g. continuous updating (real-time), near real time updating, i.e. every 10th or 15th minute, and the periodic updating, i.e. hourly, half-daily, daily, twice a week, weekly, fortnightly, monthly and more than 1 month

(*continued*)

Main characteristics	Definition of main characteristics	Sub-characteristics	Metrics[a]	Definition of metrics
				(Balasubramanian *et al.*, 2002; Caridi *et al.*, 2010, 2013; Chan, 2003; Goswami *et al.*, 2013; Klueber and O'Keefe, 2013; McIntire, 2014; Vigtil, 2007)
				The extent with which the respondents agree that the information provided by SC members are timely (Williams *et al.*, 2013) or the level of timeliness rated as high, medium and low (Goswami *et al.*, 2013)
		Information accuracy	Justification of the degree of accuracy	How close the shared data is to the actual realization (e.g. forecasted orders vs actual orders), which reflects the gap between the estimated and actual values (Wu *et al.*, 2012, 2016) or the difference between the inventory count and inventory record (Hardgrave *et al.*, 2013)
				The percentage waste of new products made after the new design had been launched (Chan, 2003). The concept uses business process performance as a proxy for an accurate information flow
				The extent with which the respondents agree that the information provided by SC members are accurate (Williams *et al.*, 2013) or the level of accuracy rated as high, medium and low (Goswami *et al.*, 2013)
		Information completeness	Amount and types of information that meet the requirement of participants	The extent to which information is shared downstream and upstream. Information is classified by users of information, e.g. buyers, suppliers (Barratt and Oke, 2007; Brandon-Jones *et al.*, 2015; Holcomb *et al.*, 2011; Jonsson and Mattsson, 2013; Kaipia and Hartiala, 2006; Kim *et al.*, 2011; Lee *et al.*, 2014; Vigtil, 2007, Wang and Wei, 2007; Williams *et al.*, 2013; Zhang *et al.*, 2011; Zhou and Benton, 2007)
				The extent to which information is shared downstream and upstream. Information is classified by functionality, e.g. master, transaction, status and plans (Caridi *et al.*, 2010, 2013; Goswami *et al.*, 2013) or by business

(*continued*)

Table IV.

Table IV.

Main characteristics	Definition of main characteristics	Sub-characteristics	Metrics[a]	Definition of metrics
				processes, e.g. manufacturing, purchasing, shipping (Goswami *et al.*, 2013; Lee *et al.*, 2014; Rai *et al.*, 2012; Wang and Wei, 2007)
Transformational characteristics	The alignment of accessed information with the business processes and the use of that information to create business value	Operational efficiency	Utilizing information to improve business process performance	Operational efficiency is realized when the shared information is integrated in the business processes and used for better decision making, e.g. improving demand forecast, updating production schedules, monitoring sales, providing alerts for abnormality and delay of products in transit, etc. Examples of business processes are product design, demand forecasting, production planning, ordering process, inventory management, manufacturing execution, delivery or logistics performance and quality management (Balasubramanian *et al.*, 2002; Barratt and Barratt, 2011; Bartlett *et al.*, 2007; Caridi *et al.*, 2014; Chan, 2003; Delen *et al.*, 2007; Goel, 2010; Heah and Omar, 2005; Kaipia and Hartiala, 2006; Kim *et al.*, 2011; Lee and Rim, 2016; McIntire, 2014; Musa *et al.*, 2014; Nooraie and Parast, 2015; Pfahl and Moxham, 2014; Rai *et al.*, 2012)
		Strategic competencies	Market-sensing capability and relationship-building capability[a]	Market-sensing capability aims to identify and seize market opportunities by sharing in-depth information and knowledge about the market (Bartlett *et al.*, 2007; Wei and Wang, 2010), or by enhancing firm's capability to meet regulatory and trade requirement (Klueber and O'Keefe, 2013) Relationship-building capability aims to increase the trustworthiness and strengthen the relationship among the firms, suppliers and customers (Kim *et al.*, 2011; Narasimhan *et al.*, 2006)

Note: [a]Examples of the metrics of the automational, informational, and transformational characteristics classified by business processes type are summarized in Table V

delivery plans of each participant are shared automatically through a joint information base system. This provides an automatic alert to the participants of any change that occurs during the delivery lead time and enables them to synchronize the delivery plans. The automational characteristics of SCV include such indicators as automated information capturing and automated information transfer/integration.

Automated information capturing primarily refers to the means of capturing information instantaneously by using the machine readable automatic identification and data capture (AIDC) technology such as linear barcode, two dimensional multi-row barcode, matrix code, contact and non-contact magnetic devices, contact memory, and radio frequency identification system or RFIDs (Griffiths *et al.*, 2009). Automated information capturing is prominent in tracking products during shipment and determining the status of inventory in the pipelines. This characteristic of SCV is highlighted by Francis (2008), Musa *et al.* (2014), and Papert *et al.* (2016), who emphasize the visibility of the object (e.g. an item, a package, a pallet, or a container) that moves through the SC. Rai *et al.* (2012) identify IT functionality in SCV as the means for capturing granular information on the flows of shipments and the status of stocks across multiple locations as well as the alerts on critical events during the in-transit journey. Automated information capturing provides the unified view of products from production planning and shipment at manufacturers, to storage and movement by freight forwarders and ocean carriers, to inspection and clearance by customs authorities, and to inland transport to final destination. More precisely, Delen *et al.* (2007) illustrate that automated information capturing refers not only to the continuous tracking of products from the distribution center to retail stores, but also includes measuring the lead time associated with each movement e.g. distribution center – store room, store room – sales floor, and sales floor – box crusher. Cherrett *et al.* (2015) identify other aspects of automated information capture, including the fill rate and stock quality (e.g. stock damage) at each depot, as well as the current location of the vehicles. Automated information capturing enables firms to trace all events that occur during the movement of products in real time and, by analyzing the recorded information, trace unusual events or inefficiencies in the process. In addition to the flow of goods, Barratt and Oke (2007), Bottani *et al.* (2010), Jonsson and Mattsson (2013), Kaipia and Hartiala (2006), Vigtil (2007), and Williams *et al.* (2013) recommend automated capturing of demand information as it is vital for product replenishment and production scheduling. In particular they focus on: sales data (point-of-sales (POS), sales forecast, demand pattern), stock withdrawal data, sell-through data (replenishment), customer orders and their updated status, back orders, market promotion, and market signals (e.g. customer preference and trends) (Wei and Wang, 2010). The last is captured through the analysis of POS data from retail stores.

Automated information transfer/integration highlights the transmission of information to generate a faster and more effective response. It involves the "sharing of information through E-space and data repository system" (Bartlett *et al.*, 2007, p. 303). Automated information transfer includes several B2B connectivities such as Electronic Data Interchange, web-based portals, or web-based applications through which SC members can access or retrieve the authorized information (Bartlett *et al.*, 2007; Caridi *et al.*, 2014; Griffiths *et al.*, 2009; Vigtil, 2007). Recent articles (e.g. Cherrett *et al.*, 2015; Papert *et al.*, 2016) also report more recent methods of information transfer – such as mobile, 3G, and smartphone applications, and GPS – being used in the pharmaceutical SC. Automated information capturing and electronic information transfer are expressed implicitly in the definitions of SCV that highlight the essence of real-time information, i.e. POS, as critical to SC planning. Although "the definition of SCV is independent of how the messages are transmitted, received and presented" (according to Francis, 2008, p. 183), the access to accurate and timely information can be reached best through advanced ICT (Barratt and Barratt, 2011; Caridi *et al.*, 2014). The automational characteristics mark the difference between

information sharing and SCV because information sharing can be realized without automated information capturing and electronic transfer through, e.g. direct/indirect contacts and meetings (Kim *et al.*, 2011).

In line with these studies, we propose to measure the automational characteristics of SCV by the levels of automated information capture and automated information transfer/integration among participants in a SC. The metric used for automated information capture is the extent to which AIDC technology is employed to capture the status and the flow of products and/or materials that are transiting along the SC. Findings from the extant literature reveal different levels of IT use ranging from manual records to fully automated systems (Balasubramanian *et al.*, 2002; Griffiths *et al.*, 2009). Likewise, the metric for automated information transfer/integration is the extent to which information sharing across organizations is conducted via IOIS systems. Practical transferring methods in the extant SCV literature range from manual transfer (e.g. fax and mails) to fully connected IOIS systems (Vigtil, 2007; Kim *et al.*, 2011). The metrics of the automational characteristics are defined in Table IV, while Table V exhibits sample metrics of automational characteristics in relation to business processes. For example, in the collaborative planning, forecasting, and replenishment process, the automational characteristics are measured by the extent of demand information (e.g. POS data, stock withdrawal) that is captured and shared electronically. Demand information in an electronic format is convenient for data analytics, e.g. analysis of customer preference and market trends.

3.2 Informational characteristics

The second set of SCV characteristics underlines the crucial importance of the quality of information for SCV and measures, SCV by the quality level of the exchanged information among upstream and downstream members of a SC. It does not emphasize the "hard side" of IT capability but rather focuses on the "soft side" of managerial capability, which is employed to improve the quality of the exchanged information, or to channel the information flow.

The quality of the information is reflected by a number of characteristics such as timeliness, accuracy, and completeness (Barratt and Barratt, 2011; Brandon-Jones *et al.*, 2015; Caridi *et al.*, 2010; McIntire, 2014; Williams *et al.*, 2013). Timeliness refers to the "frequency of information shared" (Balasubramanian *et al.*, 2002, p. 73). Real-time or near-real-time information is frequently used as a proxy for the highest quality of timeliness (Balasubramanian *et al.*, 2002; Barratt and Barratt, 2011; Caridi *et al.*, 2010; Griffiths *et al.*, 2009; Zhou and Benton, 2007). It is often accommodated by the RFID systems as the means of information capturing and transfer (Bottani *et al.* 2010; Delen *et al.*, 2007). In this regard, timeliness is related to the automational characteristics, as the technology allows the information to be communicated and processed in a timely manner. However, the frequency of information communication "needs not be real-time for meaningful and useful SCV" and is rather "dependent on the nature of the business and its customers" (Francis, 2008, p. 183). For example, in the automotive industry, the updating of information between a manufacturer of automotive supplies and its suppliers ranges from continuous updates provided every 10th or 15th minute to daily updates (Balasubramanian *et al.*, 2002, p. 76). Apart from the industry, the frequency of updating also depends on the types of information needed. For instance an hourly update is considered "fresh" for transaction events, whereas a daily update is a fresh updating for (production) master information including technical features of the product and bill of material (Caridi *et al.*, 2010). The difference in updating frequency indicates that researchers should acknowledge the type of information when deciding about the criteria for information timeliness measurement. In some instances, information timeliness is justified as high, medium, or low, or rated on a five-point scale in order to simplify the evaluation (Goswami *et al.*, 2013; Williams *et al.*, 2013).

Table V.
Sample metrics of main characteristics in relation to business processes and strategies

Automational characteristics	Informational characteristics	Transformational characteristics	Business processes/ Strategies	Improved business performance
The extent that demand information from customers is captured electronically using Barcode and scanners, or RFID technology. Examples of demand information are POS data, sales forecast, demand pattern, updated customer orders, stock withdrawal and sell-through data. (Bottani *et al.*, 2010; Kaipia and Hartiala, 2006; Vigtil, 2007; Williams *et al.*, 2013; Zhou and Benton, 2007)	Completeness/timeliness/accuracy of demand information shared downstream between manufacturer and retailer, e.g. details of demand information (sales amount, sales pattern, sales), updated frequency, and accuracy (gap between sales forecast and actual orders) (Attaran and Attaran, 2007; Williams *et al.*, 2013; Wu *et al.*, 2016)	Using demand information to forecast sales volume of the products (Barratt and Oke, 2007) Using demand information to align the supplier's production to the manufacturer's production schedule (Caridi *et al.*, 2014) Monitoring daily and hourly sales of promotional products (Barratt and Oke, 2007)	CPFR	Increased promotional forecast accuracy, increased product availability Increased production flexibility and responsiveness Mitigated bullwhip effect and reduced safety stock Increased product availability and sales opportunity
The extent of electronic demand information sharing between focal firms and their customers through collaborative planning system, web-based EDI or web-portal (Barratt and Oke, 2007; Goswami *et al.*, 2013; Jeyaraj and Sethi, 2012; Zhou and Benton, 2007)	Completeness/timeliness/accuracy of demand information shared upstream between manufacturer and supplier e.g. extent of sales data from customers shared upstream to suppliers, updated frequency, and the extent of missing/incomplete data in each order (Barratt and Oke, 2007; Brandon-Jones *et al.*, 2015; Goswami *et al.*, 2013) The extent of promotional plans and POS shared between manufacturer and retailer (Barratt and Oke, 2007; Williams *et al.*, 2013)	Using promotional plans/POS to revise sales forecast of the promotional products (Pfahl and Moxham, 2014) Using inventory information to advise replenishment/sell-through orders (Kaipia and Hartiala, 2006)		
The extent of order status tracking or sharing through automated tracking system or through a web portal (Kim *et al.*, 2011) The extent of delivery information tracking/sharing through automated tracking system, smartphone	The timeliness and accuracy of order status shared between the supplier and manufacturer (Caridi *et al.*, 2014; Lee *et al.*, 2014) The timeliness and accuracy of delivery information (e.g. ASN) shared between the supplier and	Monitoring the delivery schedules by updating the changes (quantity, delivery date) made by manufacturer and supplier (Bartlett *et al.*, 2007) Using the tracking response to improve delivery performance such as delivery speed, delivery reliability	Inbound Logistics (and Material Management)	Shorter lead times between supplier and manufacturer, reduction in component/equipment stockouts and reduction in problems related to supplier performance (e.g. late arrivals)

(*continued*)

Table V.

Automational characteristics	Informational characteristics	Transformational characteristics	Business processes/ Strategies	Improved business performance
application or through a web portal (Cherrett *et al.*, 2015; Kim *et al.*, 2011)	manufacturer (Caridi *et al.*, 2014; Rai *et al.*, 2012)	and volume flexibility (Balasubramanian *et al.*, 2002; Nooraie and Parast, 2015; Yu and Goh, 2014)		
The extent of delivery information captured in real time using RFID or mobile technology (Cherrett *et al.*, 2015; Delen *et al.*, 2007; Musa *et al.*, 2014; Papert *et al.*, 2016; Rai *et al.*, 2012)	Detail of delivery information (e.g. lead time at distribution center, lead time during journey, lead time of an item at a store) shared between manufacturer and retailers (Delen *et al.*, 2007; Lee and Rim, 2016)	Monitoring the delivery schedules by updating the changes (quantity, delivery date) made by manufacturer and retailer (Cherrett *et al.*, 2015)	Outbound logistics	Shorter lead time, improved delivery schedule adherence, increased on-time delivery, and insight into the backroom process of moving freight to the sales floor
The extent of delivery information tracking or sharing through automated tracking system or through a web portal (Cherrett *et al.*, 2015; Goel, 2010; Rai *et al.*, 2012)	The extent of information on the status of stocks and the flows of shipments (Francis, 2008; Pfahl and Moxham, 2014; Rai *et al.*, 2012)	Using real-time product movement to analyze the flow of materials between the distribution center and the retail stores (Cherrett *et al.*, 2015; Delen *et al.*, 2007)		
	The extent of instantly updated status about the state of products during transportation, between terminal operator, logistics service provider and transport manager, e.g. departure/arrival schedules, delay (Cherrett *et al.*, 2015; Goel, 2010; Nooraie and Parast, 2015)	Cascading alerts on exceptions that have occurred or are expected to occur i.e. shipment delay or damage (Cherrett *et al.*, 2015; Delen *et al.*, 2007; Musa *et al.*, 2014; Rai *et al.*, 2012)		
		Using updated status about the delay in departure and arrival schedules to determine shipments and routes (Goel, 2010)		
The extent of product design information capture/sharing through collaborative planning system, web-based EDI or web-portal (Kim *et al.*, 2011)	Details and knowledge of product design information shared between manufacturer, supplier, and customer (Chan, 2003; Narasimhan *et al.*, 2006; Wei and Wang, 2010)	Monitoring the transfer of information (changes in product design) from the top management level to the actual workers, and across the functional departments (Chan, 2003)	Product design	Accurate and fast delivery of information related to changes in specifications or designs of the product, quick product development
		Discussing the new ideas about the new product development (Wei and Wang, 2010)		

(*continued*)

Automational characteristics	Informational characteristics	Transformational characteristics	Business processes/ Strategies	Improved business performance
The extent of information integration through inter-organizational information system (e.g. collaborative planning system)	Establishing more frequent and honest contact with suppliers to increase the level of trust Communicating the firm's strategic needs to suppliers Sharing confidential information with customers Frequent communication to determine the future customer expectation Frequent discussion to understand how customers use your products and service Sharing information related to products, customers and markets (Narasimhan *et al.*, 2006; Wei and Wang, 2010)	Participating with suppliers in the joint decision making or planning processes, e.g. participating in the sourcing decision with suppliers Participating with customers in the joint decision making or planning processes, e.g. jointly plan the promotional activities or product development Developing the insight about the markets and customer preference Maintaining and developing relationships with suppliers in order to ensure the compliance to trade and regulatory requirement (Klueber and O'Keefe, 2013; Narasimhan *et al.*, 2006; Wei and Wang, 2010)	Supplier relationship Customer relationship	Reduced opportunistic behavior, increased willingness to share information, increased expectation of relationship continuity Increased customer satisfaction and customer loyalty, increased market-sensing capability

Table V.

Accuracy is another feature of the informational characteristics. It goes hand in hand with timeliness in most SCV studies. Caridi *et al.* (2010) define accuracy as the "degree of conformity of the shared information with its actual value" (p. 601). However, the notion is rather subjective and the determination of the degree of accuracy is left to individual judgment on a continuum ranging from satisfactory to unsatisfactory (Caridi *et al.*, 2010; Zhou and Benton, 2007). Chan (2003) suggests that it is good to provide accurate information, and that this could be reached by using the percentage of waste in production as an indicator of accuracy of production information. A higher percentage of waste indicates a lower accuracy of the exchanged information. On the other hand, Wu *et al.* (2012, 2016) define accuracy of demand visibility as the difference between shared demand information and actual order volume. Accuracy therefore reflects "how close shared information should be to actual realization" (Wu *et al.*, 2012, p. 2). Similarly, Hardgrave *et al.* (2013) evaluate accuracy as the "difference between the actual (inventory) on-hand and perpetual inventory (continuous record of on-hand store inventory)" (p. 847). Accordingly, we propose that accuracy should be evaluated materially based on the conformity of information to the actual values, or by using performance-based criteria.

Information completeness refers to the amount and type of information that corresponds to the needs of the users or the pertinence of the information (Francis, 2008, p. 182). Specific information to transfer should be restricted to information that "contributes to the goal of information sharing" (Balasubramanian *et al.*, 2002, p. 76). It is important to identify which information is sufficient and needed for each participant. Understanding the needs of participants "can make planning and production proceed better and faster" (Balasubramanian *et al.*, 2002, p. 77). Several studies corroborate the distinctive needs of buyers and suppliers on the types of information (Brandon-Jones *et al.*, 2015; Holcomb *et al.*, 2011; Jonsson and Mattsson, 2013; Kim *et al.*, 2011; Lee *et al.*, 2014; Vigtil, 2007; Williams *et al.*, 2013; Zhou and Benton 2007). From these studies we, derive that information from suppliers (or supply visibility) indicates the production and completion of an order. Essential information includes production planning and capacity, order completion status, back order status, delivery schedule, and lead time. On the other hand, information from buyers (or demand visibility) focuses on the level of demand and downstream inventory. Demand information includes sales information (POS and forecasts), promotion plans, customer orders, and changes of orders. Wei and Wang (2010) also suggest incorporating market knowledge and customer preferences as valuable demand signals. Inventory visibility focuses on the level of inventory in the pipeline. It ranges from inventory levels in stores (on the shelf or in the backroom) to inventory levels in warehouses and distribution centers. Additional terms of inventory-related information include stock withdrawals and replenishment volume, which indicate the level of inventory that triggers the replenishment from wholesalers to retail stores (Kaipia and Hartiala, 2006; Vigtil, 2007).

In addition to the distinctive needs of buyers and suppliers, Barratt and Barratt (2011) underline the different requirements between logistics, marketing, production, and purchasing departments. Different information requirements indicate the different types of information that are useful for each of the business functions. Wang and Wei (2007) classify the types of information as related to business processes, e.g. product/material management, transaction, process status, planning/forecasting, and operational performance assessment information. According to the authors, information completeness spans different business functions related to planning and control in the manufacturer-supplier trading process. Alternatively, Francis (2008) restricts the type of information to the identities, locations, status of entities, and events associated with the movement of products. In other words, this information relates to inbound or outbound logistics. Also Caridi *et al.* (2010) and Goswami *et al.* (2013) refer to functional-based information. They classify information along four types: transactions/events, status, master information, and operational plans.

Transaction information refers to the reporting of occurrences such as the identity, location, and time associated with an item along the transit, the flows of shipment, the flows of goods across multiple locations, and cascade alerts on exception and performance metrics. At the same time, status information describes the status of resources or processes as observed or recorded at a certain moment in time, e.g. order status, inventory status, or production capacity. Master information involves the features of products such as technical attributes and bill of materials. Operational plans contain information linked to the future plans of firms and their partners, e.g. distribution plans, production plans, sales forecasts, and promotion plans. Details of the four types of information vary with the business functions that are applicable.

3.3 Transformational characteristics

The third set of SCV characteristics, the transformational characteristics, refers to the alignment of the accessed information with the business processes and the use of that information to create business value. These characteristics express that SCV "goes beyond simple access to certain information flows" because it assures that "the exchanged information is relevant and meaningful" (Caridi *et al.*, 2014, p. 2). The transformational characteristics are classified into two groups, as summarized in Table IV. The first group relates to the improvement in operational efficiency, as information from business partners is shared and used to track, plan and monitor the business operations. The second group relates to strategic competencies, as information is used to strengthen relationships with strategic or to gain insight on the markets.

3.3.1 Operational efficiency. In business operations, information is considered useful if it creates "visibility that leads to meaningful operational benefits and enhanced business activities" (Barratt and Barratt, 2011, pp. 515, 526). Most studies have explained the utility of information in a cluster of key business processes such as product design, demand forecasting, production planning, ordering process, inventory management, manufacturing execution, delivery or logistics performance, and quality management (Balasubramanian *et al.*, 2002; Barratt and Barratt, 2011; Bartlett *et al.*, 2007; Caridi *et al.*, 2014; Chan, 2003; Delen *et al.*, 2007; Goel, 2010; Kaipia and Hartiala, 2006; Kim *et al.*, 2011; Lee and Rim, 2016; McIntire, 2014; Nooraie and Parast, 2015; Pfahl and Moxham, 2014; Rai *et al.*, 2012). To understand the relationship between transformational characteristics and business process improvement, we summarize the ways that information is aligned with decision making in the following business processes: CPFR, logistics process (inbound and outbound logistics), and new product design and development.

In demand management or specifically in the CPFR process, it makes sense to use the shared demand information from downstream members to update the demand forecasts of the upstream members. In this way, SCV can reduce demand amplification and uncertainty about the demand signal (the so-called bullwhip effect). As a result, the demand forecast is more accurate, the gap between forecasted and actual demand (actual buy after first order) is lowered and demand planning is more stable (Barratt and Barratt, 2011; Kaipia and Hartiala, 2006; Wu *et al.*, 2016). When this leads to changes in demand planning, it will consequently affect production plans. Heah and Omar (2005) identify the use of real-time alerts to notify production and distribution managers about changes, as well as the integration of demand and production planning, as indicators of improved production planning and control. The coherence in planning and manufacturing processes leads to significant inventory reduction, especially of the safety stock, the level of which is highly related to the uncertainty in order lead time (Bottani *et al.*, 2010). In addition, delivery performance (outbound logistics) can improve through different sorts of tracking, including that of the status and movement of materials and products, or of the updated inventory

level. This can shorten delivery lead time and increase delivery reliability (Balasubramanian *et al.*, 2002; Bartlett *et al.*, 2007; Cherrett *et al.*, 2015; Delen *et al.*, 2007; Goel, 2010; Rai *et al.*, 2012). Subsequently, stockout opportunities can be reduced and products can be available for the market at all times (Barratt and Barratt, 2011; Kaipia and Hartiala, 2006).

Improved visibility also improves the performance of material management on the inbound SC. In a study by Caridi *et al.* (2014), spare-part component availability is identified as one of the main causes of poor production lead time at a manufacturing firm in the aerospace industry. Timely access to accurate supplier information (e.g. advance shipping notice, order status, production plan, etc.) led to a remarkable reduction in production lead time and subsequently to a reduction in component stockouts. In the case of new product development or changes in product design, a real-time update of product specifications and an online discussion about product improvement significantly reduce the time needed to develop the new product. In this way, new products can get to market at the determined time (Chan, 2003; Kim *et al.*, 2011). In summary, the transformational characteristics of SCV transform the automational and informational characteristics (access to timely, accurate, and rich information) to multiple activities in several business processes; they consequently have the potential to improve the efficiency of processes. Examples of the metrics of transformational characteristics are exhibited in Table V.

3.3.2 Strategic competencies. In addition to having operational benefits, SCV is "an important determinant of SC competitiveness" (Kim *et al.*, 2011, p. 668) and creates strategic competencies in different ways. Exchanging demand information from downstream to upstream SC echelons reduces uncertainties in the inter-organizational relationship and, accordingly, enhances trust between the participants (Kim *et al.*, 2011, p. 668). According to the IOIS view, the high visibility of partners' internal activities creates "low incentives for opportunistic behavior" and therefore increases the "trustworthiness" of the buyer-supplier relationship (Kim *et al.*, 2011, p. 670). A greater level of trust among SC members is indicated as one of the main elements in SC strategy due to its role in supplier relationship strengthening (Narasimhan *et al.*, 2006, p. 23). From a resource-based viewpoint, trustworthy and effective SC linkages are considered to be a valuable and rare resource that cannot simply be imitated by competitors (Barratt and Oke, 2007). SCV that is capable of improving linkages in an SC relationship is termed "distinctive" SCV. Having distinctive SCV significantly improves manufacturer and supplier responsiveness in replenishing a product with quickly changing promotional activities (Barratt and Barratt, 2011, p. 521). The ability to strengthen relationships with suppliers and customers is indicated by various related aspects: the expectation of relationship continuity, participation in the sourcing decisions of suppliers, establishment of more frequent contact with suppliers and customers, communication of a firm's future strategic needs to its suppliers, creation of a greater level of trust with suppliers and customers, extension of the SC to include members beyond immediate suppliers, creation of a compatible communication/information system with suppliers, entrance into long-term contract arrangements with customers, determination of future customer expectations, increased ease for customers seeking assistance, flexibility to meet customers' changing needs, use of electronic data interchange communication, and an understanding of how customers use the firm's products and services (Kim *et al.*, 2011; Narasimhan *et al.*, 2006). Strengthening relationships is particularly important in industries in which products and SC operations are highly regulated by the government, or other regulatory bodies (Klueber and O'Keefe, 2013). It is important that suppliers are qualified and compliant with trade and regulatory standards and procedures. "Trust and power relations [among SC partners] cannot be underestimated" (Klueber and O'Keefe, 2013, p. 309) as some internal conflicts may reduce SC compliance. Relationship building is a strategically oriented aspect of SCV that should be considered for evaluation of the effectiveness of SCV.

SCV also creates the opportunity to learn and exchange knowledge between partners in a SC network. Wei and Wang (2010, p. 239) refer to this competence as the capability to "sense and seize" market opportunities, whereby partners regularly exchange information and discuss product and market situations such as the demand shift and changed customer preference. Insights into end customer demands foster product differentiation (Kim *et al.*, 2011, p. 668) and enable manufacturers and suppliers to adjust, adapt, and modify SC processes in response to changes and unexpected situations, leading to the so-called "adaptive enterprise" (Wang and Wei, 2007, p. 658). According to the dynamic capability view, market-sensing capability is indicated by these activities: the exchanging of information related to upcoming products, promotion and marketing plans, market demand trends and forecasts, demand shifts, and changes in customer preferences; and the discussion and sharing of knowledge and ideas on how to improve performance (Wei and Wang, 2010, p. 249). Examples of the transformational metrics of enhanced strategic competencies are shown in Table V.

In summary, SCV is characterized by automational (the ability to access information), informational (the quality of the information), and transformational (the utilization of information) characteristics. Automational characteristics are determined by the ability of a firm to capture information automatically and to transfer electronically the pertinent information to its business partners. Informational characteristics are determined by the accuracy, timeliness, and completeness of information. Transformational characteristics are determined by the actual utilization of the exchanged information, either to improve decision making in business processes or to increase the strategic competencies of a firm. As these characteristics are linked to business processes, SCV effectiveness is measured by the achievement of these characteristics in the processes. The three SCV characteristics that we propose in this paper provide a clear boundary and scope to SCV and support the evaluation and comparison of the effectiveness of SCV in business processes. Moreover, the metrics will facilitate the progress of SCV projects and promote SCV implementation in practice.

4. Assessment of SCV

This section aims to answer our second research question by investigating the assessment of SCV in existing studies. Among the 32 empirical studies that evaluate SCV both qualitative and quantitative approaches are found. Eight studies use a qualitative approach and evaluate SCV based on within-case and cross-case analyses. In total, 24 studies use a quantitative approach, employing more diverse analytical methods such as the arithmetic and geometric means, regression analysis, partial least squares analysis, visibility scorecards, utilization ratios, and mathematical models. Tables VI and VII categorize the samples of articles under study in terms of their assessment method, and summarize how they measure SCV.

The within-case and cross-case qualitative analyses summarized in Table VI, attempt to identify "the patterns that link the variables under investigation" (Barratt and Barratt, 2011, p. 518). In the study of Barratt and Oke (2007), the distinctiveness of visibility is interpreted based on the "quality and the extent to which the shared information is perceived as meaningful and useful" (p. 1220). The authors emphasize IOIS technology as an enabler of a distinctive SCV. The visibility level of a firm is justified as distinctive in cases in which access to information is performed through collaborative planning systems. The systems facilitate the electronic transfer of near-real-time sales information and detailed inventory levels between manufacturer and retailer. The shared information is used for promotional planning and monitoring. As in this literature review, Barratt and Oke (2007) distinguish automational, informational, and transformational characteristics of SCV. However, their conclusion on visibility levels – such as distinctive, high, and low – does not provide an

Table VI.
Samples of the qualitative methods used for the assessment of supply chain visibility effectiveness

Authors	Methods	Levels or types of visibility	Measures	Unit of analysis
Qualitative approach				
Barratt and Oke (2007), Barratt and Barratt (2011)	Within-case and cross-case analysis	Perceived level of demand and supply visibility in the external and internal linkages: distinctive, high, medium, relatively low, low, lack of visibility	Amount of information shared downstream and upstream, between the relevant functions (departments) of the same company and across the SC, the quality of information (timeliness and accuracy), the usefulness of the shared information to achieve sustainable competitive advantage (pp. 1220, 1224) Measures are informational and transformational	SC level (between focal firm, customer, and suppliers)
Bartlett *et al.* (2007)	Cross-case analysis	Transparent level of SCV (high-percentage of information sharing and collaboration), translucent level of SC visibility (partial sharing of information) and opaque level of SC visibility (lack of information sharing) (p. 296)	Types and amount of information related to cost, quality and delivery criteria (p. 299) Sub-items of cost criteria: material, overhead, sub-contract, factory, transportation, and other non-quality costs (p. 311) Sub-items of quality criteria: scrap levels, rework levels, process repeatability, supplier quality issues, audit of quality systems, and continuous improvement (p. 311) Sub-items of delivery criteria: order receipt, capacity planning, material ordering, production execution, shipment, lean manufacturing and inventory management (p. 312). Also integrated MRPs and internet tracking of shipments (p. 312) Measures are informational	Firm level (between focal firm and suppliers)
Papert *et al.* (2016)	Cross-case analysis	Logistics visibility in pharmaceutical SC, classified in four levels, ranging from lowest to highest or 0.25 to 1 (p.	SCV metrics consist of (1) availability: the sharing and accessibility of information. Metrics are the provision of central database and automatic logging of transport and temperature information, (2) identity: provision of identity information. Metrics are the provision of secure and accurate identification at drug level (product level), (3) position: spatial information at storage. Metrics are the provision of room-level precise position, (4) status-quo: information about the status-quo of the objects. Metrics are temperature sensing and record of temperature data, verification of drugs (e.g. comparing current and expiration dates, comparing drug, and vehicle destinations), and recognition of unauthorized drug removal with associated dates and positions (pp. 874-875) Measures are automational	SC level (between manufacturer, LSPs, wholesaler, and retailer

Authors	Methods	Levels or types of visibility	Measures	Unit of analysis
Quantitative approach				
Caridi *et al.* (2010, 2013)	Geometric means	Node visibility (focus on one company) and overall SCV visibility (focus on entire network) (p. 606)	Total amount of visible information, the accuracy and the freshness of information (p. 603), and the distance and significance of the firm to the focal company (pp. 603-604) Measures are informational	Firm level (between focal firm and supplier) SC level (between focal firm and suppliers from different tiers)
Brandon-Jones *et al.* (2014)	Regression analysis	Demand and inventory visibility (p. 59)	The extent to which inventory and demand levels are visible throughout the SC (p. 63) Measures are informational	Firm level (between focal firm and supplier)
Williams *et al.* (2013)	Regression analysis	Demand visibility, supply visibility and market visibility (pp. 545-546)	10 critical elements (types of information) and information quality (accuracy, timeliness, completeness and useful format) (p. 553) Measures are informational	Firm level (between focal firm and a customer or a supplier)
Brusset (2016)	Partial least squares (PLS)	Visibility capabilities (ability to deploy IT systems to track, integrate, report and plan collaboratively) (p. 50)	Extent of integrating ERP with other SCM tools, extent of deployment of track&trace IT tools, extent of deployment of reporting tools, and extent of the development of web collaborative platform (p. 50) Measures are automational	Firm level (between focal firm and a customer or a supplier)
Kim *et al.* (2011)	Partial least squares (PLS)	Visibility from buyers' perspective and from suppliers' perspective (p. 671)	Extent to which suppliers' information is visible to buyers and extent to which buyers' information is visible to suppliers, through the IOIS (p. 671) Supplier information: order completion status, back inventory status, production schedules, current production capacity and demand planning information Buyer information: inventory status, order status, production plans, production capacity, demand forecast information (p. 671) Measures are automational	Firm level (between focal firm and a customer or supplier)
Wang and Wei (2007)	Partial least squares (PLS)	Visibility in manufacturing, transaction, planning/ forecasting, product/ material management and performance evaluation (pp. 658-659)	Amount of information exchanged between trading partners in the operational functions (p. 658) Measures are informational	Firm level (between a buyer and a supplier)

(*continued*)

Table VII. Samples of the quantitative methods used for the assessment of supply chain visibility effectiveness

Authors	Methods	Levels or types of visibility	Measures	Unit of analysis
Wei and Wang (2010)	Partial least squares (PLS)	Four types of visibility: sensing, learning, coordinating and integrating (pp. 239-240)	Set of measures indicating the sensing, learning, coordinating, and integrating abilities (p. 243) Measures are transformational	Firm level (between focal firm and supplier)
McIntire (2014)	Visibility scorecards (percentage)	Effectiveness of visibility in terms of the percentage of achievement to the target	Sets of metrics indicating the sensitivity, accessibility, intelligence, and decision relevance (pp. 41-42) Measures are automational, informational and transformational	Firm level (between focal firm and supplier/ customer)
Rai *et al.* (2012)	Utilization ratio (percentage)	Effectiveness of visibility as the percentage of IT functionality implemented and used in an interfirm relationship (p. A2)	Utilization rate (p. 248) in terms of (1) the capture of granular detailed information on events, status of stocks and flows of shipment; (2) the integration of information on buyers' inventory positions and flow of goods across multiple locations; and (3) the cascade alerts on exceptions that have occurred or are expected to occur (p. 239) Measures are automational and transformational	Firm level (between logistics service provider and customer)
Lee and Rim (2016)	Mathematical model (Six Sigma *Z* scores)	Process visibility focusing on operational capabilities (p. 5)	The mean and standard deviation of the process visibility for lead time, yield, quality and utilization (p. 9) Measures are transformational	SC level (between focal firm and tier 1 supplier and retailer
Yu and Goh (2014)	Mathematical model (triangular fuzzy numbers)	SC visibility for purchased parts modeled on a scale (low, medium, high) with the corresponding triangular fuzzy numbers (p. 128)	SCV incurred if part i is supplied by supplier j. Variables are the number of suppliers (i), number of parts (j) and minimum amount of visibility needed for part i (p. 126) Measures are transformational	Firm level (between focal firm and supplier)
Zhang *et al.* (2011)	Mathematical model (set theory)	Three types of visibility: atom visibility (one actor and one type of information), single visibility (two actors, the provider and receiver, of one type of information) and compound visibility (a set of actors and a set of information items) (p. 580)	Capability of accessing information and the capability of providing information (types and amount of inventory information and the number of participants) (p. 580) Measures are informational	SC level (among several companies)

Table VII.

unambiguous indication for how to distinguish between each level. In the study of Bartlett *et al.* (2007), the levels of visibility have ranged from opaque (where no information is shared) to translucent (sharing partial information) to transparent (sharing information that leads to knowledge and collaborative abilities). Visibility is assessed in relation to the key performance criteria of each business function in three dimensions (cost, quality, and delivery). The assessment of SCV is at the firm level. Similar to the previous study, the authors do not elaborate on the assessment: while they explain the criteria (e.g. the type of information needed for cost, quality, and delivery assessment), they do not provide details about the scales, e.g. how to distinguish the accessibility and quality of information in the translucent and transparent levels. Non-measurable scales are also found in the study of Klueber and O'Keefe (2013), which evaluates the level of SCV in a regulated SC (in the aviation industry). The study focuses on the strategic dimension of SCV and emphasizes such transformational metrics as strengthened relationship, ability to pursue business opportunity, qualification of SC partners to comply with regulatory and trade requirements, and operational flexibility. Although the dimensions of SCV are clearly defined, the criteria to distinguish levels of achievement are subject to individual interpretation. The ambiguity of the evaluation scales is found mostly in the informational and transformational metrics; the situation is better for automational metrics. Papert *et al.* (2016), who evaluate the level of SCV based on auto-ID technology, define the criteria for different levels of auto-ID functions. For example, data storage capacity (in the availability dimension) is classified as low (data volume in kilobyte range), medium (data volume in megabyte range), and high (data volume in gigabyte range) using certain definitions and measurable scales.

From a quantitative approach (see Table VII), different types of estimates for the level of SCV are used. One group of studies focuses mainly on the informational characteristics. Caridi *et al.* (2010) estimate the level of SCV at the firm level by calculating the geometric mean of three information properties: amount, accuracy, and freshness of information exchanged between a manufacturer and a supplier. To estimate the level of SCV for the entire SC, the authors add two more variables to the formula: the distance between the focal company and the suppliers (measured by the number of echelons) and the significance of the suppliers to a focal company. Caridi *et al.*'s measurement is applicable to both the dyadic level (between the focal company and a supplier) and the SC level. However, it is mainly focused on the informational, and ignores the automational and transformational characteristics. For example, the assessment leaves unexplained whether or not information is captured and exchanged automatically among participants in a supply network. Based on the work of Caridi *et al.* (2010), Williams *et al.* (2013) estimate SCV according to the informational characteristics (variety of information, accuracy, timeliness, completeness, and usefulness of format). The results of their analysis indicate that, statistically, SCV should be considered from a holistic point of view, covering demand, supply, and market visibility. In other words, the scope of information completeness should "span both the upstream-downstream and market partner dimensions" (Williams *et al.*, 2013, p. 548). The holistic view of SCV assessment is also found in the study of Holcomb *et al.* (2011), Wang and Wei (2007), and Zhang *et al.* (2011). The SCV assessment of Zhang *et al.* (2011) covers both upstream (demand) and downstream (supply) visibility, even though their analytical methods are different. Holcomb *et al.* (2011) estimate the SCV level by the average scores of the metrics in each category. Wang and Wei (2007) estimate the level of visibility at the firm level using the partial least squares method based on the mean values of survey data. These estimated SCV levels reflect only the information completeness characteristics of SCV. Zhang *et al.* (2011) calculate the level of inventory visibility based on set theory. Set theory considers a SC as a finite set of actors and a finite set of information items that are shared among them. In the study, a set of information items comprises the amount of inventory-related information, e.g. the weekly and monthly inventory levels.

The set of actors refers to SC participants (e.g. manufacturers, distributors, and retailers) that are the providers and receivers of that information. The level of visibility is calculated as the proportion of visible information to all available information, either at the firm or SC level.

In contrast to the focus on informational characteristics in the studies discussed above, automational characteristics are the main focus in a number of studies, e.g. Brusset (2016), Delen *et al.* (2007), Kim *et al.* (2011), and Rai *et al.* (2012). Brusset (2016) assesses the SCV level from IT capabilities, such as having integrated ERP and SCM tools, track and trace tools, or a web collaborative platform. Delen *et al.* (2007) assess the level of SCV based on the automated capturing of products delivered from a distribution center to a retail shop. The transit times of products along the distribution channels are captured automatically by RFIDs which therefore provide abundant information in real time. This information is used to calculate the mean time between transits of each product. Kim *et al.* (2011) estimate the level of SCV by the extent to which the exchanged information is provided through the IOIS system, which allows the integration of partner with firm IT systems. In this sense, SCV means that each partner sees the other's information in real time. The level of SCV is computed as a mean value of scores dedicated to the different types of information. Rai *et al.* (2012) estimate the visibility level by comparing the percentage of buyer logistics transactions with supplier logistics transactions by using IT. The transactions mainly focus on the automated capturing of the logistics information, e.g. inventory level, product flow information, and exceptional events occurring during shipments.

Transformational characteristics receive greater attention in recent SCV studies (Lee and Rim, 2016; McIntire, 2014; Wei and Wang, 2010; Yu and Goh, 2014). These studies recognize that SCV is about not only the abundance and quality of information, but also the automated capture of information. Lee and Rim (2016) calculate the SCV level based on the mean and standard deviation of visibility for lead time, yield, quality, and utilization in business processes. McIntire (2014) estimates the level of SCV by the ability to capture, integrate, update, and make use of information. The effectiveness of SCV is estimated based on the percentage by which SCV metrics have achieved the target. These metrics indicate the levels of sensitivity (data capture), accessibility (data integration), intelligence (self-updating of changes and alerts), and decision relevance (providing solutions). Yu and Goh (2014) propose a fuzzy multi-objective decision-making approach to model SCV and SC risk from an operational perspective. SCV is defined by the level of spare parts provided by the suppliers. Wei and Wang (2010) define SCV as the capability to sense changes in the market, gain knowledge from partners, manage SC relationships, and achieve goal congruence in the SC. It estimates the level of SCV by the mean scores of metrics that constitute the four constructs of SCV.

The SCV assessments summarized in Tables VI and VII confirm the relevance of the three main characteristics of SCV identified earlier. The most prominent metric is the extent of visible information or information completeness (found in 40 articles), followed by the automated information transfer/integration (22 articles), the automated information capture and information timeliness (both characteristics are found in 21 articles), and information accuracy (19 articles). As for the transformational characteristics, the concept of operational efficiency appears in 18 articles, while strategic competencies are studied in five articles only. Most quantitative papers are partial since they focus on only one or two aspects of SCV.

5. Discussion and research agenda

By means of a systematic review synthesis, we aim to gain insights into the main characteristics of SCV and the ways in which SCV can be assessed at the firm level. We observe that there are common and distinct characteristics attributed to the measurement of SCV that need to be discussed.

A first important observation is that most studies examine and measure SCV from an automational and/or informational point of view, with only a few papers evaluating SCV effectiveness on its transformational characteristics. Various authors (e.g. Barratt and Oke, 2007; Kaipia and Hartiala, 2006) have recognized this shortcoming and have usefulness of information as a metric of SCV performance. In response, Wei and Wang (2010) propose to measure the effectiveness of SCV based on improved market learning and trust-building capabilities, while Caridi *et al.* (2014), McIntire (2014), and Lee and Rim (2016) measure the effectiveness of SCV by the extent to which visibility is used to automate decision making, or reduce the performance gap in business processes. Nevertheless, the number of existing papers that identify the transformational effect is much lower than those that identify automational and informational effects. We therefore call for more studies on this relevant issue.

Second, the relationship between SCV and business performance is not clearly demonstrated in the existing SCV literature due to the lack of metrics that connect the effectiveness of SCV to operational processes. We suggest that the measures of SCV effectiveness should demonstrate the cause-effect relationship between SCV and business performance, e.g. by measuring how SCV induces changes to business processes and, as a consequence, improves the operational efficiency and strategic competencies of a firm. McIntire (2014) calls the ambiguity of these relationships a "black box of visibility processes": SCV is assumed to have a direct impact on business performance and the effectiveness of SCV is measured by changes in overall business outcome. This approach to SCV measurement ignores the fact that improvements in business outcome (e.g. reduced inventory level) are the result of a variety of SC initiatives that are conducted in parallel with SCV. We propose that the effectiveness of SCV should indicate the changes in business processes and illustrate how visible information leads to better decision making and planning.

Third, we derive from our literature review that the objectivity of the metrics of SCV effectiveness is low. Linked to this limitation, we propose future research to further exploit the quantitative metrics, which have been in the minority as compared to qualitative metrics, in the existing SCV literature. Quantitative metrics can demonstrate the progress of SCV, i.e. how its effectiveness increases or decreases in a given period (Klueber and O'Keefe, 2013). We observed a gap in the sense that metrics tracing the utilization of information in business processes are under researched. In this paper, we define a set of metrics in a number of processes. Future research may investigate the potentiality of using these metrics in different processes and in various industries. We suggest that the metrics should be tested statistically on a wide scale to generalize the correlation between the metrics and business performance, e.g. operational efficiency, strategic competencies.

As a fourth and last topic for further research, we call for a better understanding of how SCV emerges, develops, and must be implemented to be successful. According to a recent KPMG International Cooperative(2016) report, only a handful global manufacturing companies are able to expand SCV beyond tier 1 suppliers. The most significant barriers to visibility are created by organizational factors rather than technological factors (Butner, 2010). Organizational silos, unwillingness to share information, lack of time, lack of rewarding systems, and increased levels of work are the primary concerns. Investigating the roles of organizational and technological factors and estimating the mutual benefits for the participants on SCV would provide a better understanding of SCV, as well as an increased chance of its successful diffusion into organizational practices. This kind of research could tackle the implementation barriers felt by SC executives in several market analyses (e.g. Butner, 2010) and link SCV to operational performance metrics.

All of the points raised above are linked to the fact that SCV means different things to different companies (Butner, 2010; McIntire, 2014) which hinders the progress of promoting SCV projects (McIntire, 2014). As shown in Table IV, information completeness (the type and

amount of information) varies between users, both at the SC level (i.e. role as supplier, manufacturer, distributor, or retailer) and the business functions level. Regardless of the types of visibility, we propose researchers and practitioners should explicitly define the intended participants and business functions, identify the specific information needs in relation to these dimensions, and design quantitative measurement scales, such as the percentage of information exchanged between distinct participants. In addition, informational characteristics should reflect their relation to business performance as illustrated in Table V. Overall, we believe that clear agreements between all players involved in the SC can help to solve the issues raised above, and unlock the full potential of SCV projects.

6. Conclusion

This paper revisited SCV to assess what research insights can be deduced from extant research on its characteristics and effectiveness. We used a process-oriented perspective along which we propose to characterize SCV by its automational, informational, and transformational characteristics: SCV can be considered as a process that captures and transfers accurate, timely, and complete information among business partners in a SC (Williams *et al.*, 2013). Based on a systematic literature review, we found that most SCV literature assumes that SCV has a direct impact on business process improvement and evaluates the effectiveness of SCV by its automational and informational characteristics. In contrast, we argue that an assessment of SCV should be based on the three characteristics together, therefore enabling firms to evaluate the extent to which they excel in terms of accessible, high quality, and useful information.

This study makes two main contributions to the SC literature. To begin, it is the first paper that provides a systematic review on the characteristics of SCV, and synthesizes the metrics to be used for evaluating the effectiveness of SCV. By using a systematic review approach, we were able to analyze, interpret, and integrate the various views on the characteristics of SCV. Our process-oriented approach allowed us to express the importance of information accessibility as an automational characteristic, the quality of information as an informational characteristic, and the usefulness of the information as a transformational aspect of SCV. In this way, we respond to calls for a deeper understanding of the concept of SCV, expressed not only in academia (Barratt and Barratt, 2011; Williams *et al.*, 2013), but also in practice (McIntire, 2014). Second, through the lens of the process-oriented approach, we identify a set of metrics that relate the effectiveness of SCV to business performance. Process-oriented thinking provides the basis for business value assessment at the process level and has been adopted in several SCM studies (Horzella, 2005; Lambert *et al.*, 2005; Visich *et al.*, 2009). Considering the effectiveness of SCV in multiple SC processes provides a more comprehensive explanation of the usage of information and its impact on business performances. We explicitly listed the measures of SCV effectiveness described in the extant literature so that our literature review might support future empirical research on SCV metrics and how they affect business process performance. Future research can depart from our overview of metrics to study which metric has most impact on the performance of business processes.

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